Increasing Potassium Conductance ($\overline{G}_K$) Increases the Threshold Amplitude in the Hodgkin-Huxley Model

Victor Sai

Daniar Hussain

6.021J

26 November 2002

Introduction

- Caffeine *facilitates neural excitation* by decreasing threshold for activation
- Caffeine causes a rise in $[Ca^{2+}]_{in}$, which results in rhythmic increases in G_K

→ *Hypothesis*: Does increasing $\overline{G}_K$ decreases the threshold for activation in the Hodgkin-Huxley model?

Methods

- Definition of Action Potential: $V_{max} > 0$
- Calculation of Threshold: MATLAB script running H-H space and current clamped model

Binary Search Algorithm

[1] Bracket threshold interval on [0.1, 100] mA

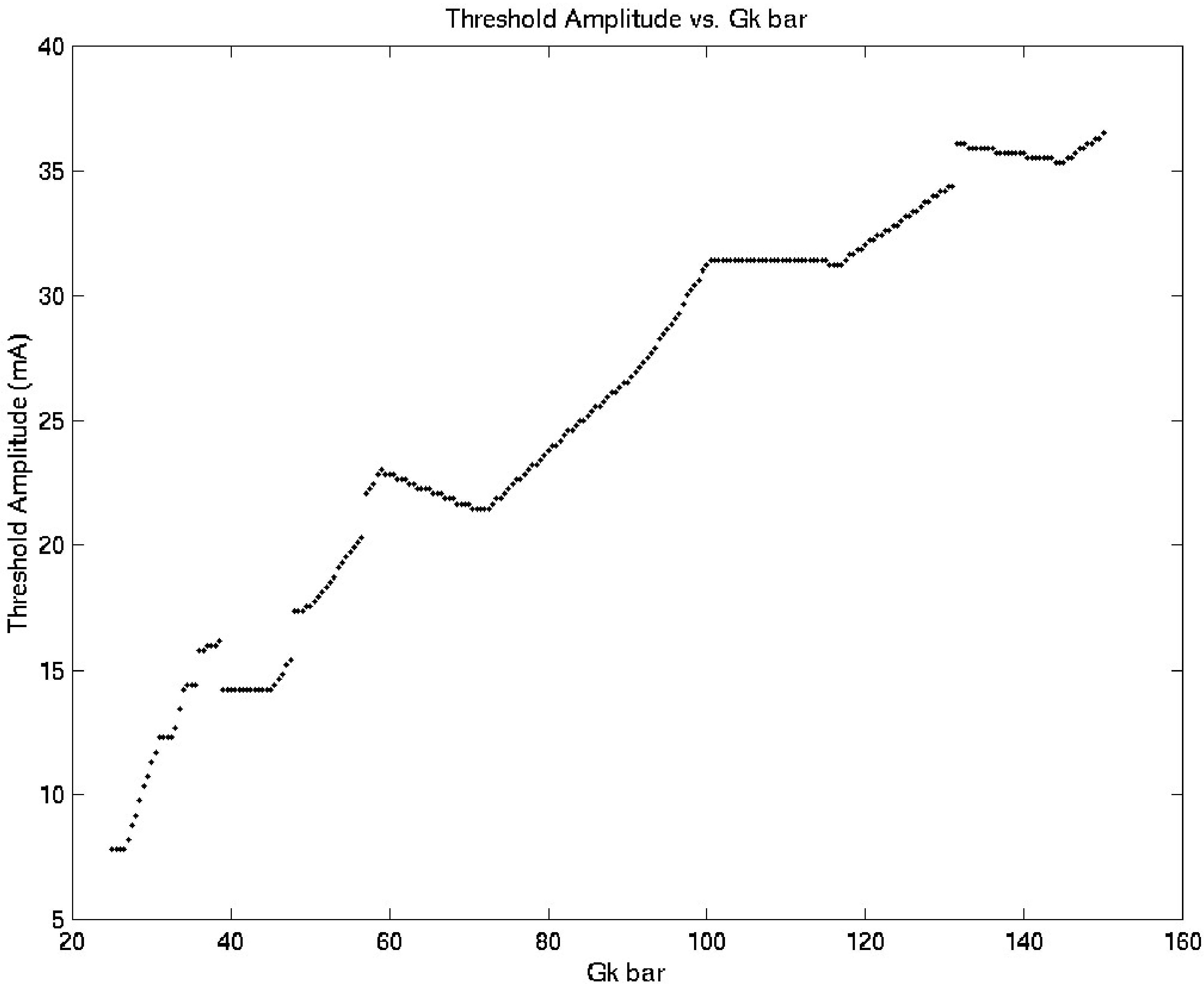
[2] Run model to determine $V_m(z)$ at midpoint of interval

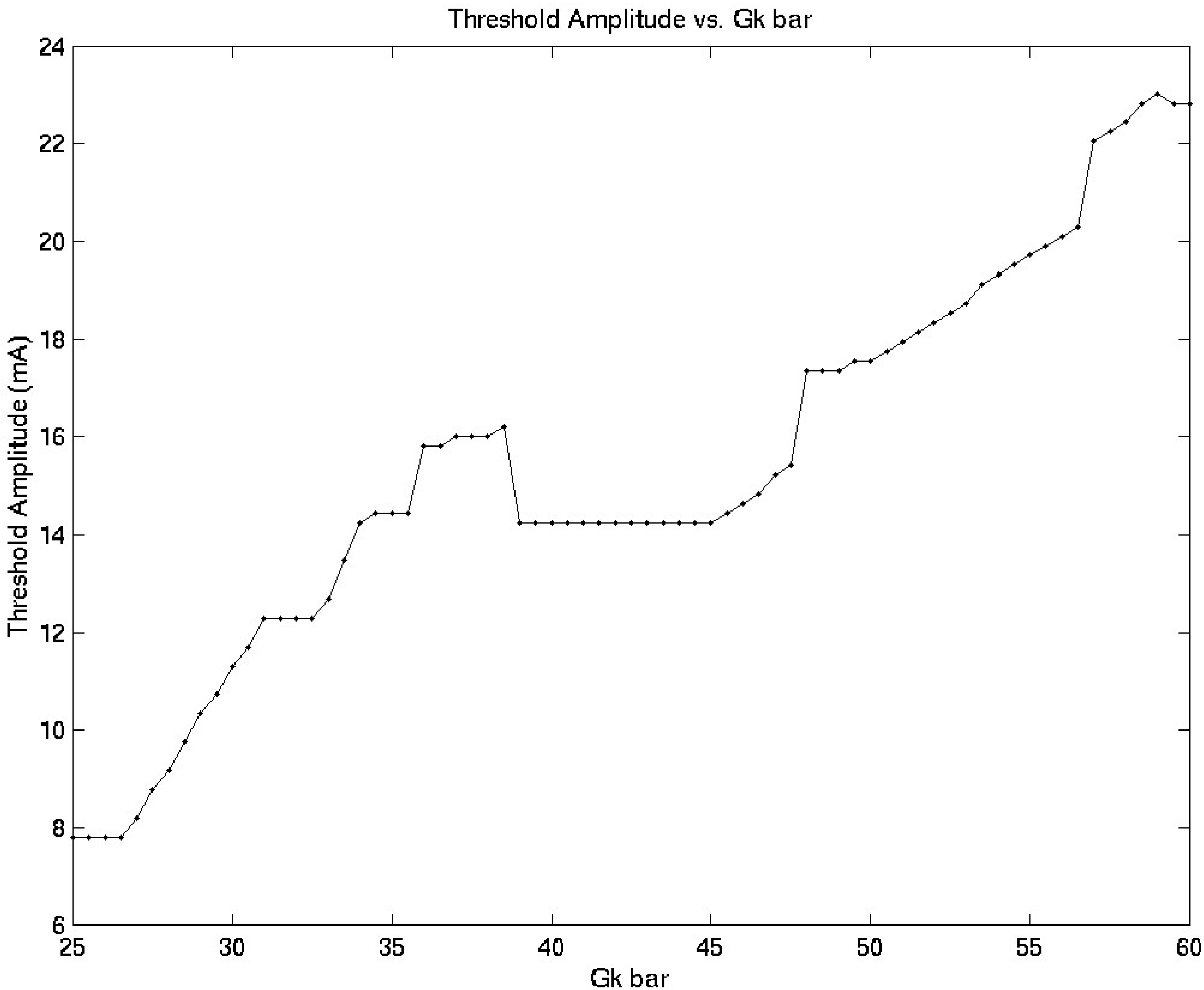
[3] If $V_{max} > 0$, set upper bound as midpoint;
otherwise set lower bound as midpoint

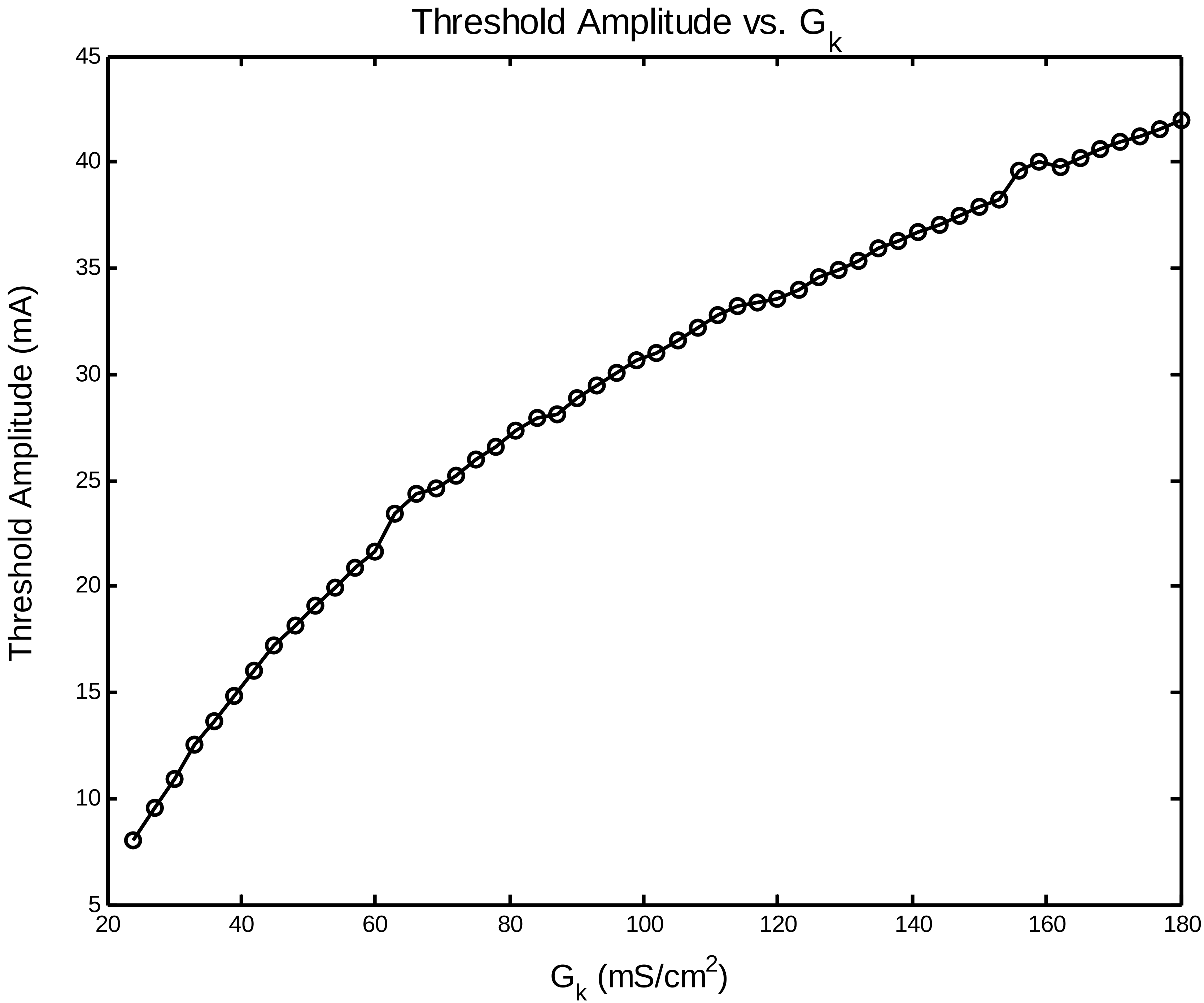
[4] Continue (go to step [2]) until desired precision met

Results

- $\overline{G_K}$ ↑ then threshold amplitude ↑
- Threshold amplitude saturates


Threshold Amplitude vs. Gk bar
Threshold Amplitude (mA)
Gk bar
40
35
30
25
20
15
10
5
20
40
60
80
100
120
140
160

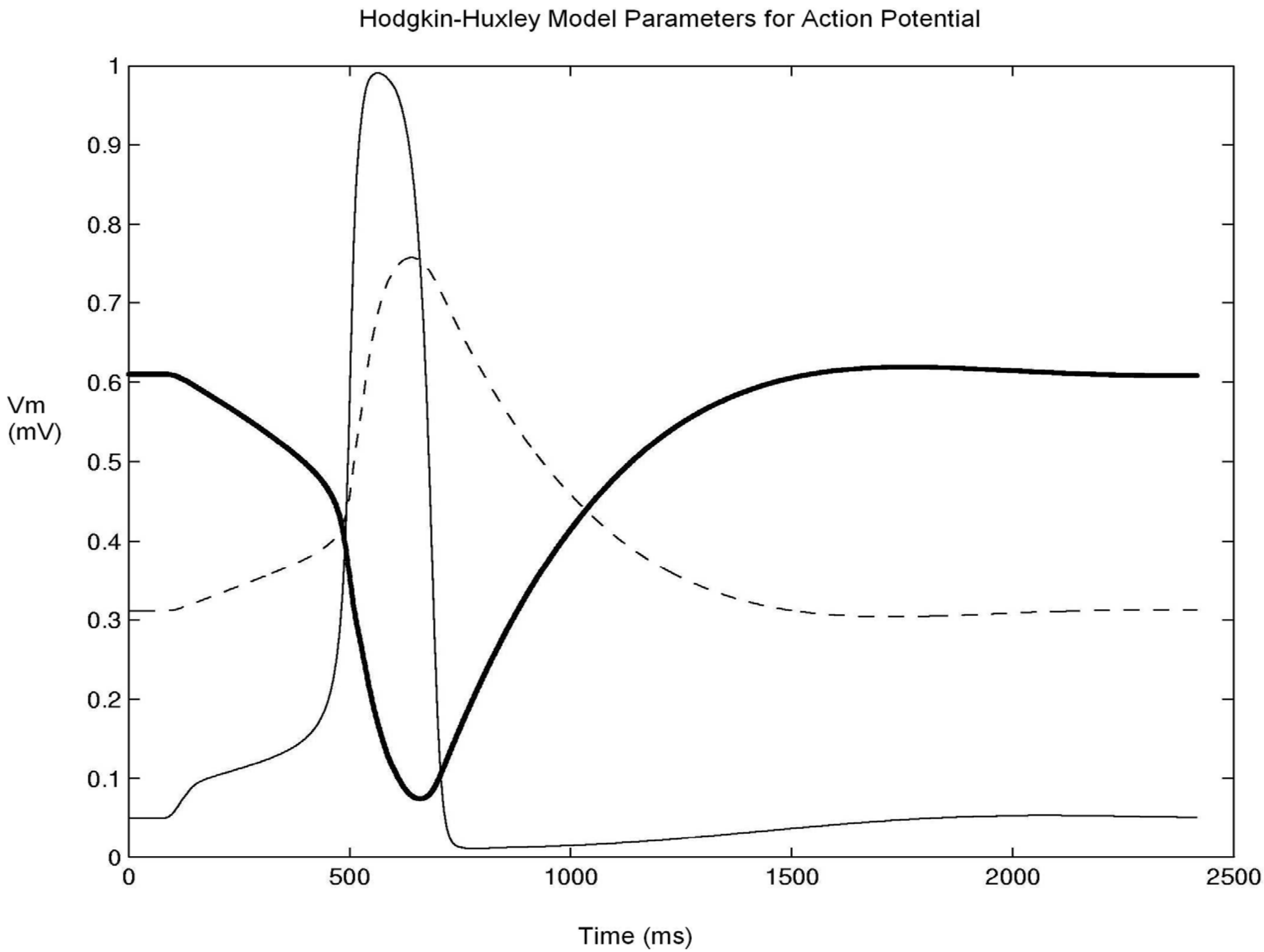

Threshold Amplitude vs. Gk bar
Threshold Amplitude (mA)
Gk bar
24
22
20
18
16
14
12
10
8
6
25
30
35
40
45
50
55
60



Threshold Amplitude vs. G_k
Threshold Amplitude (mA)
G_k (mS/cm^2)
45
40
35
30
25
20
15
10
5
20
40
60
80
100
120
140
160
180

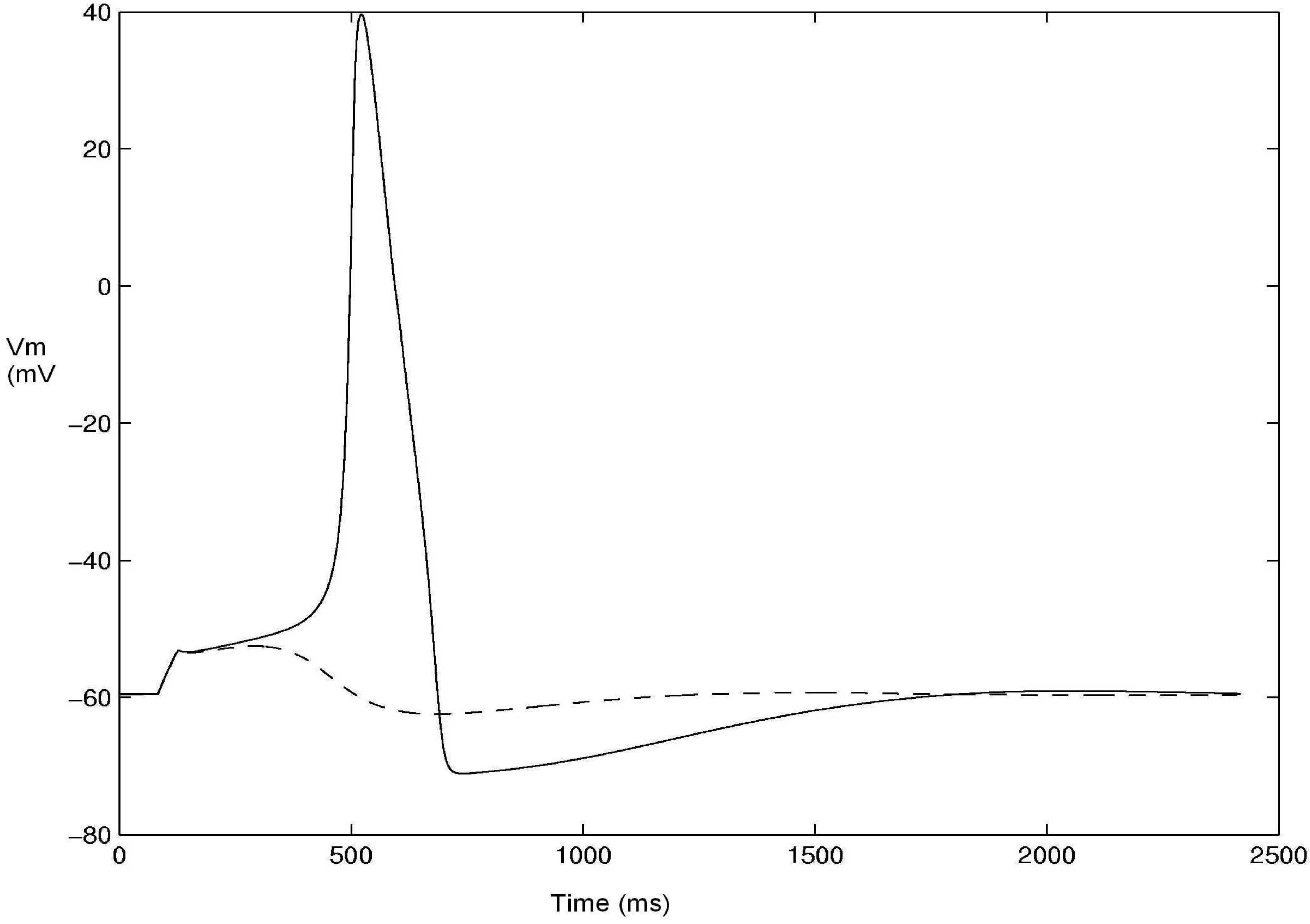
Discussion

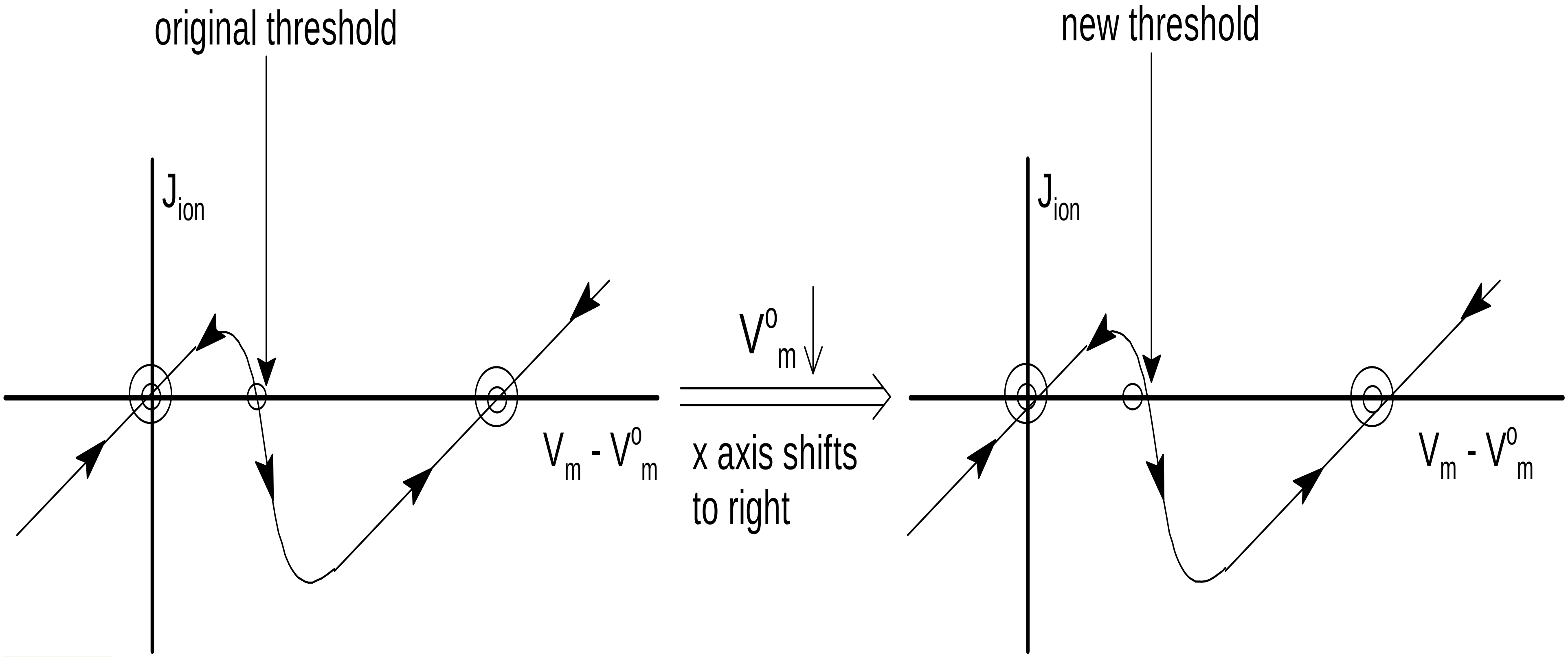
- Why does threshold increase as G_K increases?
- Why does threshold saturate as G_K increases?


Hodgkin-Huxley Model Parameters for Action Potential
Vm
(mV)
Time (ms)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
500
1000
1500
2000
2500

M, N, H graph here without Action Potential

Action Potentials for Gk Near Threshold





- Since $V_m{}^\circ$ is a weighted sum of Nernst potentials, as G_k increases, V_K = --50 mV makes a larger contribution, and $V_m{}^\circ$ decreases.
- The decrease in $V_m{}^\circ$ results in a shift to the right of the *x-axis* of the equilibrium curve, which leads to a higher threshold.

Why does threshold saturate as $\overline{G}_K$ increases?

$$\mathbf{V_m^o} = \frac{G_K}{G_m} * \mathbf{V_K} + \frac{G_{NA}}{Gm} * \mathbf{V_{Na}} + \frac{G_L}{Gm} * \mathbf{V_L}$$

VK =

VNa =

- As $\overline{G}_K$ increases, it begins to dominate over $\overline{G}_{Na}$, which leads to less incremental decrease in V_m°
- Less incremental decrease in V_m° results in a smaller increase in threshold, thereby leading to saturation

Conclusions

- Increasing $\overline{G_K}$ increases the threshold amplitude, contrary to expectation
- But caffeine lowers the threshold of activation…
- *Therefore, caffeine's interaction with neurons is **not** via $\overline{G_K}$*